DOCUMENT RESUME

ED 159 007 SE 024 751

TITLE Aquatic Pest Control. Manual 99.
INSTITUTION Missouri Univ., Columbia. Agricultural Experiment Station.; Missouri Univ., Columbia. Extension Div.
PUB DATE [77]
NOTE 39p.; For related documents, see SE 024 748-750 and SE 024 665-671; Contains occasional light and broken type

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Certification; Entomology; Environment; Herbicides; *Instructional Materials; *Pesticides; *Post Secondary Education; Safety; Units of Study; Water Pollution Control; *Weeds
IDENTIFIERS *Missouri; *Water

ABSTRACT

This training manual provides information needed to meet the minimum EPA standards for certification as a commercial applicator of pesticides in the aquatic pest control category. The text discusses various water use situations; aquatic weed identification; herbicide use and effects; and aquatic insects and their control. (CS)

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AQUATIC PEST CONTROL

manual 99

This manual was developed in cooperation with The Missouri Department of Agriculture and the Coop Extension Service, University of Missouri.

Assembled by Members of Extension Pesticide Training Team

SE 024 751

AQUATIC PEST CONTROL

Certification of Commercial Applicators

Restricted Use Pesticides
for
Aquatic Pest Control

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Standards of Competency for Certification of Commercial Applicators who plan to use "Restricted Pesticides" for Aquatic Pest Control for Iowa, Kansas, Missouri, and Nebraska.

Section 1. Standards for Certification of Commercial Applicators

Section 171.4, Federal Insecticide, Fungicide and Rodenticide Act, as amended in 1972 contains provisions for general and specific standards of competency for each category of commercial applicators.

For the category of Aquatic Pest Control the provisions of the federal law are:

"Applicators shall demonstrate practical knowledge of the secondary effects which can be caused by improper applications rates, incorrect formulations, and faulty application of restricted use pesticides used in this category. They shall demonstrate practical knowledge of various water use situations and the potential of downstream effects. Further, they must have practical knowledge concerning potential pesticide effects on plants, fish, birds, beneficial insects and other organisms which may be present in aquatic environments. These applicators shall demonstrate practical knowledge of the principles of limited area application."

Definitions are given in Section 171.2 of the Federal Insecticide, Fungicide and Rodenticide, as amended in 1972. The term "practical knowledge" means the possession of pertinent facts and comprehension together with the ability to use them in dealing with specific problems and situations.

Section 2. Introduction

The purpose of this training manual is to provide you with practical information on aquatic pest control in accordance with the provisions for standards of competency designated in Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1972. This manual does not contain information on identification and control of each aquatic weed in various water use situations. Neither does it contain information on only "restricted use" pesticides since at the time this manual was written classification of pesticides for aquatic pest control had not been made by EPA. Rather this publication contains some information on aquatic plants and it also contains information on herbicides that are presently registered for aquatic pest control.

A. Aquatic Weeds

Excessive growth of aquatic vegetation often prevents the optimum use of water in that area. Aquatic plants are classified by a similar growth habit as: (1) Algae, (2) Submerged, (3) Emersed, (4) Marginal, and (5) Floating.

1. Algae: Two major forms of fresh water algae are phytoplankton (planktonic) and filamentous. Planktonic and filamentous algae may clog filters in water treatment plants, produce undesirable tastes and odors in drinking water. Filamentous algae interfere with irrigation systems by clinging to structures and concrete linings and clogging weirs and screens. In ponds and lakes filamentous algae can reduce fish population. Species of filamentous algae are considered a nuisance wherever they occur. Important filamentous algae include: spirogyra (Spirogyra spp.) cladophora (Cladophora spp.), pithophora (Pithophora spp.), and chara (Chara spp.).

2. Submersed Plants: Most submersed plants are true seed plants with roots, stems, and leaves. Rooted on the bottom these plants grow chiefly below the surface although their flowers and seeds and a few leaves may extend above it. A maximum depth of 10 to 12 feet in clear water is the limit of habitat for most submersed plants. Important submersed weeds include: pondweeds (Potamogeton spp.), elodea (Elodea spp.) watermilfoil (Myriophyllum spp.) coontail (Ceratophyllum spp.) naiads (Najas spp.), bladderwort (Utricularia spp.) and buttercup (Ranunculus spp.).

3. Emersed Plants: Emersed plants are those plants that are rooted in the bottom and produce most of their leaves and flowers at or above the surface. Leaf shape, size and point of attachment are variable within this group. Leaves of emersed plants do not rise and fall with the water level as do those of attached floating plants. Important emersed weeds include: lotus (Nelumbo spp.), waterlilies (Nymphaea spp.), watershield (Brasenia spp.), arrowhead (Sagittaria spp.), water primrose (Jussiaea spp.), and water willow (Justicia spp.).

4. Marginal Weeds: Marginal weeds are emersed weeds that can and frequently grow on saturated soil above the water surface. These weeds vary in size, shape and habital. They may be found growing in moist soils along shorelines into water up to two feet in depth. Important marginal weeds are: reeds (Phragmites spp.), sedge (Carex spp.), bulrush (Scirpus spp.), cattails (Thypha spp.), smartweeds (Polygonum spp.), willow (Salix spp.), cottonwood (Populus spp.), salt cedar (Tamarix spp.), and rushes (Juncus spp.).

5. Floating Plants: Some plants are free floating while others rooted in the bottom have floating leaves that rise or fall with the water level. Many floating plants reproduce rapidly and are among the most troublesome aquatic weeds. Duckweeds (Lemna spp.) and watermeal (Wolfia spp.) are important weeds in this group.

B. Identification and Control

1. Identification: In order to provide effective control of one or more target weed species in a water use area, the target weed(s) must be correctly identified so that selection and application can be made with the appropriate control practice. For identification of unfamiliar aquatic plants, take samples of entire plants (roots, stems, leaves and flowers if available) to your local county Extension agent which can be forwarded to your state land grant university for proper identification. Aquatic plants can also be identified by sending them to your State Conservation Department.

2. Control: Herbicides are frequently the preferred method for control of aquatic weeds in providing effective, longer lasting control than other methods. However even the most effective chemical methods frequently must be combined with hand or mechanical weeding to remove remaining weeds and to prevent future spread by seed or other plant parts.

C. Proper Use of Herbicides

All chemicals used for aquatic pest control should be applied in accordance with the directions on the manufacturer's label, as registered under the Federal Insecticide, Fungicide, and Rodenticide Act. Most herbicides have a low acute oral toxicity but a few aquatic herbicides are poisonous to human beings, livestock and other non-target organisms. Some herbicides are toxic to fish but most do not injure fish at concentrations required for weed control.

Proper use of herbicides includes: 1. Selection of an appropriate herbicide to control the identified target weeds, 2. Consulting with Federal or State game and fish departments for advice if a proposed herbicide application might endanger wildlife, fish or their habitat, 3. Application of the herbicide in accordance with all directions, warnings and precautions on the label, 4. Storage of excess pesticides under lock and key -- out of reach of children, animals -- and away from food and feed, and 5. Proper disposal of empty pesticide containers. Proper use of herbicides will result in most effective control of aquatic weeds and least or no effect on non-target organisms.

Table 1. Impounded (static) Water Areas -- Ponds, Lakes, and Reservoirs

Herbicides registered for use in impounded water areas	Remarks	Potential of downstream effect
Copper sulfate[1]	Low in toxicity	Should not cause hazards to non-target organisms in impounded waters or in overflow water from impounded areas if herbicides are applied as directed on the label
Dichlobenil	same as above	same as above
Dichlone	same as above	same as above
2,4-D	same as above	same as above
Diquat	same as above	same as above
Endothall	same as above	same as above
Fenac	same as above	same as above
Silvex	same as above	same as above
Sodium arsenite	Poisonous to human beings, livestock, birds, and many other non-target organisms	Ponds having continuous overflow or those likely to overflow must have their water levels lowered to prevent loss for at least 3 days. Ponds fed with large streams should not be treated.

[1] The Environmental Protection Agency has registered and established a tolerance in potable water in impounded water areas for use of only copper sulfate (1 ppm) and 2,4-D (0.1 ppm). A concentration of 1 ppm copper sulfate is equal to 4.3 ppm copper sulfate pentahydrate crystals.

Table 2. Flowing Water Areas

Herbicides registered for use in flowing water areas	Use	Potential of downstream effect
Arolein	Control of submersed weeds in flowing canals and ditches	General cell toxicant that kills by destroying vital enzyme systems in plant cells. Remains in water 2 to 3 days but poorly absorbed by plants.
Diquat	Control of submersed weeds in flowing canals and ditches	Rapidly absorbed by plant foliage quickly stopping photosynthesis in a wide range of weeds and grasses. Inactivated on contact with clay particles in soil. Water contaminated with diquat would be a hazard downstream if used for drinking, animal consumption, swimming or spraying before end of waiting period as designated on label.
Monuron Diuron	Irrigation and drainage ditches during the non-crop season where ditch not in use. If at least 4 inches of rain is not received after treatment, fill ditch with water--let stand 72 hours, then drain before use.	Application of diuron or monuron according to label directions should result in no detrimental effect to non-target organisms downstream.

Table 3. Water Saturated Areas -- Marginal Lands Bordering Various Areas of Water

Herbicides registered for use in water saturated areas	Vegetation	Site	Potential of downstream effect
i. Lakes, Ponds, etc.			
AMS	Undesirable vegetation	Adjacent and surrounding water supply reservoirs, supply streams, lakes, ponds	Proper use of Ammate X-NI formulation (registered for use adjacent to domestic water supply areas) of AMS will not cause a hazard to fish or other non-target organisms.

Table 3. (Continued)

Herbicides registered for use in water saturated areas	Vegetation	Site	Potential of downstream effect
Diquat	Marginal weeds	Edges and other portions of ponds, lakes, ditches, laterals, canals, waterways	Water contaminated with diquat would be a hazard downstream if used for drinking, animal consumption or other domestic purposes, swimming, or spraying before end of waiting period as designated on label.
2. Drainage Ditches & Drainage Ditchbanks			
Amitrole	Aquatic weeds	Marshes, drainage ditches, drainage ditchbanks	Contaminated water would be a hazard if used for fish, irrigation, drinking or other domestic purposes.
Dalapon	Perennial grasses and cattails	Drainage ditches	Should not be hazard if used as recommended on label.
Fenac	Submerged weeds in	Lakes, drainage ditches, ponds & reservoirs not used for irrigation	Contaminated water hazard if used for domestic purposes or livestock drinking.
2,4-DP	Brush	Drainage ditchbanks	Contaminated water toxic to fish and an additional hazard if used for irrigation or domestic purposes.
DSMA & MSMA	Sedge, etc.	Drainage ditchbanks	Contaminated water a hazard if used for domestic consumption by animals, wildlife, aquatic life or irrigation.

Table 4. Outer Ditchbanks

Herbicides registered for use on outer ditchbanks	Vegetation	Site	Potential of downstream effect
Picloram	Perennials	Outer banks of ditches	Since picloram is water soluble, water contaminated by this chemical would be a hazard if used for irrigation, drinking, or other domestic purpose.

Section 4. Potential Herbicide Effects

This section contains information on the potential pesticide effects on plants, fish, birds, beneficial insects and other organisms which may be present in aquatic environments.

ACROLEIN

1. *Chemical name:* Acrylaldehyde

2. *Trade names includes:* Aqualin Herbicide -- Shell Chemical Company
   Magnacide H -- Magna Corporation

3. *EPA Registration:*

Site	Use and Limitations
Moving water: irrigation canals drainage ditches	Treated water reaching crops must not exceed 13.8 ppm. Do not use where treated water flows or transfers to potential sources of drinking water. Apply by direct pumping and meter into water at rates prescribed in manufacturer's handbook.

4. *Aquatic Weeds Controlled:*

   a. Submerged plants (pondweeds, naiads, horned pondweed, coontails, Spirogyra, elodea, and others)

   b. Floating plants (water cress, water hyancinth, water primrose, water stargrass, and water starwort)

   c. Algae (*Chara, Cladophora, Hydrodictyon, and Spirogyra)*

5. *Effect on plants:* Cell toxicant which destroys enzyme systems in plant cells. Disruption of physiological processes within minutes of contact. The dead plant tissues disintegrate and float down stream in 3 or 4 days to 2 weeks depending on temperature. Little effect on marginal weeds such as cattails at dosages sufficient to control submersed plants. Vapor or direct contact of foliage with solutions can be toxic to crops. At normal concentrations used for aquatic weed control the chemical does not appear to move the soil, enter the roots or translocate.

6. *Toxicity to fish:* Carp and threadfin shad are particularly sensitive, being killed at 1-2 ppm. Black bass, blue gill, and lamprey eel larvae appear to tolerate up to 5 ppm. In a number of canals certain fish have been observed to swim ahead of the main wave and thus avoid destruction. This suggests that trace quantities of the herbicide or repellents released into the stream a few minutes before commencing treatment may be helpful in preventing kill of the fish. Fish apparently move out of the wave before the product of concentration and time reaches a toxic level, while in faster moving streams the wave overruns them.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 46 mg/kg

   b. Toxicity to skin -- Skin contact with liquid is the chief occupational hazard (may cause chemical burns). 1 ppm of acrolein in air produces detectable eye and nose irritation in 2 to 3 min. and is intolerable in 5 min.

   c. Aquatic organisms -- Magnacide H applied at 1 gal/cfs during 30-60 minutes to canals moving one or more miles/hour have killed a variety of fish, frogs, snails, crayfish and muskrats. In very slow moving drains similar dosages caused little kill.

AMITROLE

1. *Chemical name:* 3-amino-s-triazole (3-amino -1,2,4-triazole)

2. *Trade names include:* Amizole, Weedazol -- Achem Products, Inc.
Amino Triazole Weed Killer -- American Cyanamid Corp.

3. *EPA Registration:*

Site	Use and Limitations
Aquatic Areas	Do not allow spray or drift to contaminate edible crops or water which will be used for irrigation, drinking or other domestic purposes. Do not apply to water where fish are present.
Moving water drainage canals drainage ditches ditchbanks marshes	Cattail control. Apply (ground or aerial) after catkins are fully developed until frost. Phragmite control. Apply (ground or aerial) after plants are 30 in. tall until early fruiting stage.

4. *Aquatic weeds controlled:* Cattails, horsetail rush, sedge.

5. *Effect on plants:* Absorbed slowly. Good translocation. Inhibits chlorophyll formation and regrowth from buds. Spray drift from this product may injure desirable vegetation.

6. *Toxicity to fish:* Not toxic to fish or wildlife when used as recommended. Tests with bluegills indicated that all fish would be expected to survive a concentration of 1470 ppm. A concentration of 10,000 ppm. was necessary to kill 50 percent of the bluegills during a 48 hour exposure.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 24,600 mg/kg

   b. Toxicity to skin -- Minimal dermal irritation; no evidence of systemic toxicity

   c. Microbial breakdown -- Approximately 2 to 3 weeks in moist warm soil

AMS

1. *Chemical name:* Ammonium sulfamate

2. *Trade names:* Ammate X, Ammate X-NI -- Du Pont

3. *EPA Registration:*

Use	Limitations
Noncrop areas around lakes, ponds, reservoirs, streams	Apply as full coverage spray on weeds and brush. Aim spray away from water and spray away from cropland.

4. *Plants controlled:* Effective in killing most woody plants including hardwood and coniferous species. Also is an effective contact spray for control of herbaceous perennials as well as most annual broadleaf weeds and grasses.

5. *Effect on plants:* Rapidly absorbed through foliage and green stems. Translocation has been demonstrated in woody plants.

6. *Toxicity to fish and wildlife:* LC_{50} for channel catfish at 96 hours: 203 ppm. Results indicate that the use of AMS weed and brush killer in weeding out trees does not endanger deer. A formulation of 0.8 pound of the chemical in 1 gallon of water, with or without wetting agent, was reported not to kill fish although frogs were blinded by the spray.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effects on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 3900 mg/kg

   b. Toxicity to skin -- Repeated applications of 20% or 50% aqueous solutions of AMS to shaved skin of rats caused no irritation, and no signs of systemic toxicity.

   c. Microbial breakdown -- Both fungi and bacteria convert sulfamate to sulfate.

COPPER SULFATE

1. *Chemical name:* Copper sulfate (pentahyrate)

2. *Trade names include:* Bluestone -- Tennessee Corporation, Phelps Dodge Refining Corporation

3. *EPA Registration:*

Use	Tolerance ppm	Limitations
Water: Impounded Lakes Ponds Reservoirs	1.0 (in water)	Algae control. Apply over water surface.
Irrigation conveyance systems	1.0 (in potable water)	Algae control. Begin continuous addition of granular crystals after water is turned into system and continue throughout irrigation season.

4. *Aquatic weeds controlled:* Algae and stonewort in most waters.

5. *Effect on plants:* If applied uniformly, at the proper time and in the proper dosage copper sulfate is not injurious to desirable forms of plant life.

6. *Toxicity to fish:* The toxicity of copper sulfate to fish varies with the species and exposure period, and the physical and chemical characteristics of the water. Fish have been more resistant to copper sulfate in hard alkaline waters than in soft, acid waters. It is toxic to many species of fish at concentrations above 1 ppm, which is very close to rates required for aquatic weed control. Limiting safe dosage of copper sulfate for fish in parts per million is: Trout, 0.14; carp, 0.33; suckers, 0.33; catfish, 0.40; pickerel, 0.40; gold fish, 0.50; perch, 0.67; sunfish, 1.35; and black bass, 2.00.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 300 mg/kg

   b. Toxicity to skin --

   c. Aquatic organisms -- This chemical can kill snails but is not injurious to desirable forms of plant and animal life if applied uniformly at the proper time and in the proper dosage.

DALAPON

1. *Chemical name:* 2,2-dichloropropionic acid

2. *Trade names include:* Dowpon M - Dow Chemical Co.

3. *EPA Registration:*

Sites	Use and Limitations
Aquatic areas	
adjacent to water berm areas drainage ditches	Apply when grass is actively growing, before heading stage. Fall treatment is effective during catkin development. Wet all foliage.

4. *Aquatic weeds controlled:* Perennial grasses and cattails

5. *Effect on plants:* Absorbed by both roots and leaves. Easily washed off foliage. Translocates readily throughout plant. Accumulates in young tissue. Is not degraded in plants.

6. *Toxicity to fish:* Goldfish mortality at the end of 24 hr exposure was 0% at 100 ppm and 100% at 500 ppm and above. In static water on twelve species of fish including rainbow trout and coho salmon, the LC_{50} was greater than 100 ppm of dalapon which represents a very low order of toxicity to fish.

7. *Toxicity to birds:* LD_{50} -- chick (mixed): 5660 mg/kg

8. *Toxicity to beneficial insects:* In short exposure tests the no effect level of dalapon for dragonflies and stoneflies is at least 200 ppm.

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- male rat: 9330 mg/kg

   b. Toxicity to skin -- Moderate irritation, even a mild burns, upon repeated prolonged contact. Occasional contact not likely to cause significant irritation. Not absorbed through the skin in toxic amounts.

   c. Aquatic organisms -- In short exposure tests, the no effect level of dalapon for snails and several crustaceons is at least 200 ppm.

   d. Microbial breakdown -- Breaks down rapidly and completely in soil. Several organisms have been isolated and identified.

DICHLOBENIL

1. *Chemical name:* 2,6-dichlorobenzonitrile

2. *Trade names include:* Casoron 10G -- Thompson-Hayward Chemical Company

3. *EPA Registration:*

Use	Limitations
Water: Ponds Reservoirs Lakes	Broadcast to exposed bottoms or to water surface in early spring. Do not use treated water for irrigation or for human or livestock consumption. Do not use fish for food or feed within 90 days after treatment.

4. *Aquatic weeds controlled:* Elodea, northern water milfoil, naiads, coontail, chara, pondweeds (*Photamogeton* spp.).

5. *Effect on plants:* Dichlobenil is absorbed from the soil by the root system. Translocation from the roots into the aerial parts is fast. It is a powerful inhibitor of germination and of actively dividing meristems and acts primarily on growing points and root tips.

6. *Toxicity to fish:* Dichlobenil is not acutely toxic to fish at herbicidal concentrations. The range of the LC_{50} is 10 to 20 ppmw for pumpkinseed, bluegill and large mouth bass.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- male rat: 3160 mg/kg

   b. Toxicity to skin -- The acute dermal LD_{50} on albino rabbits is 1350 mb/kg. No significant local skin reactions were noted among animals at any of the dose levels tested.

   c. Wildlife -- No adverse effects on wildlife have been noticed in the tests for the herbicidal evaluation of this product.

2,4-DP

1. *Chemical name:* 2-(2,4-dichlorophenoxy) propionic acid

2. *Trade anmes include:* Weedone 2,4-DP -- Amchem Products, Inc.

3. *EPA Registration:*

Use	Limitations
Drainage ditch banks	Do not graze dairy animals on treated areas within 6 weeks after application. Do not slaughter meat animals grazing on treated areas within 2 weeks after application. Keep out of any body of water.

4. *Plants controlled:* Brush, post oak, blackjack oak, sand, shinney oak and sandsage.

5. *Effect on plants:*

6. *Toxicity to fish:* This product is toxic to fish.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 800 mg/kg

   b. Toxicity to skin -- Dermal LD_{50} -- mice: 1400 mg/kg. 2.4% solution did not irritate skin.

2,4-D

1. *Chemical name:* (2,4-dichlorophenoxy) acetic acid

2. *Trade names:* Numerous -- Amchem Products, Inc.
Chipman Division; Rhodia, Inc.;
Dow Chemical Company

3. *EPA Registration:*

Use	Tolerance ppm	Limitations
Aquatic sites:	0.1	
Lakes	(potable water)	
Ponds		
Emerged marginal weeds		Apply to weeds before seeds are formed.
Floating weeds		Apply as coarse spray when weeds are actively growing.
Submerged weeds		Apply as granular form in spring broadcasting from boat or shore, and on ice in winter.

4. *Aquatic weeds controlled:* Broadleaf weeds.

5. *Effect on plants:* 2,4-D is a systemic herbicide and is widely used for control of broadleaf weeds. Plant roots absorb salt forms of 2,4-D most readily. Leaves absorb ester forms most readily. A rain-free period of 4 to 6 hours usually is adequate for uptake and effective weed control. Following foliar absorption, 2,4-D translocation within the phloem, probably moving with food material. Accumulation of the herbicide occurs principally at the meistemic regions of shoots and roots.

6. *Toxicity to fish:* Pure 2,4-D acid at 100 ppm caused slight mortality for fingerling bream and largemouth base. This is well above the rate used in practical application.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:* Apparently 2,4-D has little or no biological activity on insects, nematodes, or plant pathogeus.

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} of various formulations fall in the range of 300 to 1000 mg/kg for rats, guinea pigs, and rabbits on a weight basis.

   b. Toxicity to skin -- Some formulations may cause skin irritation.

   c. Microbial breakdown -- 2,4-D undergoes microbial breakdown in warm, moist soil.

DIQUAT

1. *Chemical name:* 6,7-dichydro-dipyrido [1,2-a:2,1-c] pyrazimediron

2. *Trade names include:* Othro Diquat -- Chevron Chemical Company

3. *EPA Registration:*

Use	Tolerance ppm	Limitations
Agricultural premises: Canals Lakes Ponds	0.01 (as cation)	Apply in 150-200 gallons of spray to foliage of floating weeds. Inject below water surface for control of submerged weeds. Do not use treated water for humans or animal consumption, spraying or for overhead irrigation within 10 days after treatment. Do not apply to muddy water.

4. *Aquatic weeds controlled:*

   a. Submerged weeds -- Bladderwort, coontail, elodea, naiads, pondweeds (except Potamogeton robbinsii) water milfoil.

   b. Floating weeds -- Pennywort, salvinia, waterhyacinth, and water lettuce.

   c. Marginal weeds -- Cattails

   d. Algae -- Spirogyra spp. and Pithospora spp.

5. *Effect on plants:* Very rapidly absorbed by foliage. Very resistant to removal by rain.

6. *Toxicity to fish and wildlife:* Generally safe to wildlife and fish.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rat: 230 mg diquat ion/kg

   b. Toxicity to skin -- Acute dermal LD_{50} for rabbit is greater than 400 mg ion/kg. The concentrate is irritant to skin and to the eye.

   c. Microbial breakdown -- Diquat may be subject to attack by micro-organisms.

DIURON

1. *Chemical name:* 3-(3,4-dichlorophenyl)-1,1-dimethylurea

2. *Trade names include:* Karmex -- Du Pont

3. *EPA Registration:*

Use	Limitations
Irrigation and drainage ditches	Apply only during noncropseason and when ditch is not in use.

4. *Plants controlled:* Many annual and perennial grasses and herbaceous weeds.

5. *Effect on plants:* Diuron is most readily absorbed through the root system; less so through foliage and stems.

6. *Toxicity to fish:* LC_{50} values for fish range from 3 to 60 ppm depending on exposures, size and species.

7. *Toxicity to birds:* Low in toxicity; LC_{50} -- 8 days 1730 ppm for bobwhite quail; greater than 5000 ppm for Japanese quail, pheasant and mallard ducklings.

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 3400 mg/kg

   b. Toxicity to skin -- In skin tests with guinea pigs, application of a 50% aqueous paste of diuron was nonirritating to intact skin and moderately irritating to broken skin.

   c. Microbial breakdown -- Microbes are the primary factor in the disappearance of diuron from soils.

ENDOTHALL

1. *Chemical name:* 7-oxabicyo 2,2,1 heptane-2,3-dicarboxylic acid

2. *Trade names include:* Aquathol plus, Aquathol K, Hydrothol 47 -- Pennwalt Corporation

3. *EPA Registration*

Use	Limitations
Agricultural premises: Irrigation and drainage canals Lakes Ponds	Apply to surface or inject below surface when weeds are actively growing. Do not use fish from treated water for food or feed within 3 days after treatment. (See labels for waiting period before use of treated water for irrigation, livestock or domestic purposes after treatment.

4. *Aquatic weeds controlled:* Submersed weeds and other weeds for some formulations. Refer to product labels for information on aquatic weeds controlled by different formulations.

5. *Effect on plants:* The compound is selectively toxic to plants.

6. *Toxicity to fish:* Endothall used at 40 ppm had no harmful effects on three species of minnows in 96 hours. Other work demonstrates no fish toxicity to endothall in 21 days at a level of 100 ppm. The lethal dose to bluegills is greater than 100 ppm but less than 200 ppm. No mortality was observed at 10 ppm on rainbow trout, bass and fathead minnows.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity (technical) -- LD_{50} -- rats: 38 to 51 mg/kg for acid (technical)
   206 mg/kg for amine salt (66.7% formulation)

   b. Toxicity to skin -- May be absorbed through skin, causing light to moderate irritation. More severe effects at concentrations over 1%, with an immediate burning sensation on abraded skin. Also irritating to nose, eyes, and throat. Greatest occupational hazard is eye irritation caused by burning of tissues on exposure.

   c. Microbial breakdown -- Disappears from soil and water by microbiological breakdown at rates dependent upon soil temperature, moisture, type, and microbiologird activity.

DSMA and MSMA

1. *Chemical names:* Disodium methanearsonate and monosodium methanearsonate

2. *Trade names include:* Ansar -- Ansul Company
   Trans-Vert -- Amchem Products, Inc.
   Weed-Hoe
   Weed-E-Rad -- Vineland Chemical Company

3. *EPA Registration:*

Use	Limitations
Agricultural premises: Drainage ditchbanks	Apply to weeds. Repeat when weeds reappear. Do not graze treated areas. Do not contaminate waters used for domestic consumption, or by animals, wildlife and aquatic life, or for irrigation purposes.

4. *Weeds controlled:* Johnsongrass, nutsedge and other weeds or drainage ditchbanks.

5. *Effect on plants:* Chlorosis and desiccation result after a postemergent application of MSMA on susceptible plants such as johnsongrass. Research has shown that C^{14} labeled methanearsonate is translocated throughout the johnsongrass plant.

6. *Toxicity to fish:*

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 1800 mg/kg

   b. Toxicity to skin -- The skin irritation of these various arsenicals vary from very mild to none, depending on the acidity or alkalinity of each preparation and the skin sensitivity of the exposed individual.

   c. Behavior in or on soils -- Almost completely inactivated in soil by surface adsorption and ion exchange.

FENAC

1. *Chemical name:* (2,3,6-trichlorophenyl) acetic acid

2. *Trade name:* Fenac -- Amchem Products, Inc.

3. *EPA Registration:*

Site	Limitations
Lakes, drainage ditches, farm ponds and reservoirs not used for irrigation purposes	Apply to exposed lake, ditch or pond bottom following drawdown or draining. Complete drawdown is not necessary. Expose only the area to be treated. Do not use treated water for domestic purposes or livestock drinking.

4. *Aquatic weeds controlled:* Pondweeds (American, leafy, sago, waterthread and American elodea), southern naiad, watergrass, coontail, milfoil sp. and slender spikerrush.

5. *Effect on plants:* Primarily root absorbed. Not translocated by leaves.

6. *Toxicity to fish and wildlife:* No toxicity to fish or wildlife when used as recommended.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 1780 mg/kg

   b. Toxicity to skin -- Rabbits: slight irritation from 3160 mg/kg

   c. Microbial breakdown -- Very slow

1. *Chemical name:* 3-(p-chlorophenyl)-1,1-dimethylurea

2. *Trade name:* Telvar

3. *EPA Registration:*

Use	Limitations
Irrigation and Drainage ditches	Apply during noncrop season and ditch is not in use. Waste first water after treatment before irrigating crops.

4. *Weeds controlled:* Most annual and perennial weeds.

5. *Effect on plants:* Monuron is most readily absorbed through root system; less so through foliage and stems.

6. *Toxicity to fish and wildlife:* LC_{50} values for fish range from 15 to 110 ppm depending on exposure, size and species.

7. *Toxicity to birds:* Low in toxicity. LC_{50} -- 8 days was 4628 ppm for pheasant; greater than 5000 ppm for bobwhite quail, Japanese quail, and mallard ducklings.

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 3600 mg/kg

   b. Toxicity to skin -- In skin tests with guinea pigs, application of a 33% aqueous paste of monuron producted no irritation of either intact or abraded skin.

   c. Microbial breakdown -- Microbes are the primary factor in the disappearance of monuron from soils.

PICLORAM

1. *Chemical name:* 4-amino-3,5,6-trichloropicolinic acid

2. *Trade name:* Tordon

3. *EPA Registration:*

Site	Use
Aquatic areas Adjacent to water Outer ditch banks	Do not move treated soil. Do not graze or use treated areas for crop production until chemical is inactivated (about 3 years). Do not apply where surface or subsurface ground water can run onto croplands.

4. *Weeds controlled:* Annual and perennial broadleaf weeds on non-cropland.

5. *Effect on plants:* Rapidly absorbed by both tops and roots. Translocate both up and down plants. Accumulates in new growth.

6. *Toxicity to fish and wildlife:* Picloram has a low order of toxicity to wildlife and fish.

7. *Toxicity to birds:* Acute oral LD_{50} -- chicks: Approximately 6000 mg/kg

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 8200 mg/kg

   b. Toxicity to skin -- Skin - mild irritation, not a skin sensitizer to humans. Not likely to be absorbed through skin. LD_{50} for rabbits from skin absorption $\rightarrow$ 4,000 mg/kg, the highest level tested.

   c. Microbial breakdown -- Degradation by soil microorganisms occurs slowly.

SILVEX

1. *Chemical name:* 2-(2,4,5-trichlorophenoxy) propionic acid

2. *Trade names include:* Aqua-Vex -- Pennwalt
   Kuron -- Dow Chemical Company
   Weedone 2,4,5-TP -- Amchem Products, Inc.

3. *EPA Registration:*

Use	Limitations
Aquatic sites: Lakes Ponds Emerged weeds Submerged weeds	Apply when emerged or submerged weeds are actively growing. Repeat up to 6 weeks before freezing. Do not treat more than 1/2 area in any one month. Do not contaminate water intended for domestic, irrigation, or crop spraying purposes.

4. *Aquatic weeds controlled:*

   a. Submerged weeds -- Milfoil, fanwort, bladderwort, and waterweed

   b. Emerged weeds -- Waterlily, spatterdock, pickerelweed and arrowhead

5. *Effect on plants:* Absorption of silvex is similar to 2,4-D. It is absorbed through roots and foliage. Ester forms are generally more effective as foliage sprays than salts.

6. *Toxicity to fish and wildlife:* There is considerable variation between the toxicity of various derivatives of silvex to aquatic organisms. Some esters of silvex can kill fish at concentrations as low as 1 ppm. Not ordinarily harmful to other animals when used according to label directions.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 650 mg/kg

   b. Toxicity to skin -- May cause skin irritation

   c. Microbial breakdown -- Degradation is slower than for 2,4-D

SODIUM ARSENITE

1. *Chemical name:* Arsenic trioxide

2. *Trade names include:* Atlas "A" -- Chipman Division of Rodia Inc.

3. *EPA Registration:*

   (Listed but no information in EPA Compendium of Registered Pesticides, Volume I Herbicides received April, 1975).

4. *Aquatic weeds controlled:*

   a. Algae -- *Hydrodictyon, Cladophora, and Zygnema*

   b. Submerged weeds -- Coontail, waterweed, water milfoil, pondweeds (curly-leaf, american, leafy, and fine-leaf), horned pondweed, naiads, parrot feather, bladderworts, and water stargrass.

5. *Effect on plants:* A few days after treatment affected plants turn brown, become limp and sink to the bottom where they begin to decay. Water may become brownish in color to turbid during this period.

6. *Toxicity to fish:* No harmful effects to fish from the use of sodium arsenite if applied as directed. Application of sodium arsenite in excess of 10 ppm or a longer exposure will kill fish. The toxicity of sodium arsenite to fish varies with species, concentration and time of exposure. The following concentrations of sodium arsenite, expressed as ppm arsenic, have been reported as lethal, toxic, or otherwise deleterious to aquatic organisms: Fish, 1.0 - 2.0; pink salmon, 5.0 at 10 days, rainbow trout, 20 at 36 hours; and minnows, 20 at 36 hours. Fish are reported to be sensitive to sub-lethal doses of sodium arsenite and will generally swim away into fresh water.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} --

   b. Toxicity to skin --

XYLENE

1. *Chemical name:* Aromatic hydrocarbon

2. *Trade names include:*

3. *EPA Registration:*

Use	Limitations
Agricultural premises: Canal & Pond Bottoms	Drain water off site. When bottom is dry apply full coverage spray. Do not refill site for 5 days after application.
Water (irrigation)	Inject into water. Retreat downstream at 1/2 dose as needed. Treated water may be used for furrow or flood irrigation. Note: Tolerance exemption (for irrigation water) applies only with the following conditions: 1. When applied by Bureau of Reclamation, US Department of Interior, and 2. When it is applied as a emulsion at an initial concentration less than 750 ppm, and, 3. It is not applied where it may potentially contaminate row water used as a source for potable water or where return flows of such treated irrigation water into rivers and streams would contain residues greater than 10 ppm.

4. *Aquatic weeds controlled:*

5. *Effect on plants:*

6. *Toxicity to fish:* The toxicity of xylene reported to kill fish varies from 10 to 90 ppm, depending on the species, temperature, and isomer of xylene.

7. *Toxicity to birds:*

8. *Toxicity to beneficial insects:*

9. *Effect on other organisms:*

   a. Acute oral toxicity -- LD_{50} -- rats: 2000 mg/kg

   b. Toxicity to skin --

Section 5. Secondary Effects of Improper Use of Restricted Use Pesticides

A. Improper Application Rates

Proper use of herbicides involves accurate application so that water, vegetation, or soil in an aquatic area is covered uniformly at the rate as recommended on the product label. Properly functioning, accurately calibrated equipment is essential. Application of a herbicide below the rate recommended on the label can result in unsatisfactory control of target aquatic weeds. Herbicide application at a rate higher than the recommended rate for the product can result in greater residue, toxicity and hazard as result of use of the contaminated water if it is used for: drinking, fish, livestock, fish, other nontarget organisms, irrigation, or other purposes.

B. Incorrect Formulation

The use of an incorrect formulation can result in: 1. Use of a product that is not safe and may not be registered by EPA for use in that aquatic site, 2. Increased toxicity resulting in death or injury to fish and other non-target organisms, 3. Increased hazard to human beings during application, 4. Increased hazard of injury to desirable non-target plants, and 5. Increase in contamination of water that may be used for drinking, livestock, irrigation or other uses.

C. Faulty Application

Faulty application can be the result of application as a result of: 1. Improperly calibrated equipment, 2. Use of improper herbicide, 3. Use of improper rate of recommended formulation, 4. Application at improper stage of plant growth of target weeds, 5. Application of foliar applied herbicides when weeds are growing under unfavorable growing conditions, 6. Application to plants, water, or areas not registered for treatment on product label, and 7. Application during windy or other undesirable weather conditions. Hazards as result of faulty application are reported above under Improper Application Rates and Incorrect Formulations.

Section 6. Principles of Limited Area Application for Herbicides

Treatment of dense weed growth in aquatic sites including lakes, ponds, reservoirs can result in oxygen loss due to decomposition of dead weeds. To avoid fish suffocating from loss of oxygen treat only a portion of the body of water at one time in accordance with directions on the herbicide label. Information on limited area application for specific herbicides is given below.

Acrolein -- When treating ponds and lakes, fish kill can be avoided by treating half the area allowing fish to migrate to the untreated side. After the material has dissipated (approximately 48 hours) treat the other side of the area.

Diquat -- Treatment of dense weed areas can result in oxygen loss from dissipation of dead weeds. The loss can cause fish suffocation. Therefore treat only 1/3 to 1/2 of the dense weed areas at a time and wait 10-14 days between treatments. Do not apply to muddy water.

Endothall -- In areas containing heavy dense vegetation, the area should be treated in sections 5 to 7 days apart so as to prevent the death of fish due to decaying vegetation using up a large portion of oxygen present in water.

Silvex -- Treatment of aquatic weeds can result in oxygen loss from decomposition of dead weeds. This loss can cause fish suffocation. Therefore treat 1/3 to 1/2 of water area in a single operation and wait 10 to 14 days between treatments. It is recommended that treatment be applied to pond edges or lake shoreline first so that fish will not be trapped in shallow pockets on inlets.

Sodium arsenite -- If an entire pond is to be treated do only 1/2 of the area at a time and wait a week to 10 days before treating the other half. This delay between applications will allow plant decay in the treated area to progress beyond the point of heaviest oxygen consumption, before the second half is treated.

Section 7. Aquatic Insect Control

There are times when control of certain aquatic insect pests is necessary. Such instances involve the control of insect vectors of human and animal diseases or a temporary reduction in the nuisance effect of high insect populations to surrounding households.

Non-chemical means of control are preferred, but are usually too slow in emergency situations. Insecticides are usually the recommended control due to the necessity for rapid reduction of pest populations. The cost of pesticides and their usually quick but temporary control must be balanced with non-chemical methods that may give much longer-lasting reductions in pest populations, even though these may be initially more expensive.

Non-chemical methods of pest reduction should be built into each program from its conception, and then carried on throughout the operation of the program. These methods include:

1. Design of impoundment
2. Maintenance of impoundment - shore-line vegetation and algae control
3. Operation of impoundment - No overload with adequate aeration and circulation
4. Water management
5. Sanitation practices
6. Mechanical methods

Insect Pests

Mosquitoes may be of public health importance by serving as vectors of human and animal disease. But, more often, they are a nuisance. There are between fifty and sixty species of mosquitoes occurring in Missouri of which approximately six are known vectors of human and/or animal diseases.

Of the four stages in the life cycle of a mosquito (egg, larva, pupa and adult), the first three stages occur in water. The largae are called "wigglers" and the pupae are called "tumblers". Each species of mosquito has its preferred type of habitat, feeds only on certain animals, and most females require a blood meal before they are capable of laying eggs. Only female mosquitoes suck blood from their host(s). Some species prefer to remain close to their larval habitat, flying only a few hundred feet, while other species are capable of flying ten or more miles.

Filling, draining, water management, and use of mosquito-eating fish (Gambusia species) are time proven and still effective means of mosquito control.

The use of insecticides to control the larval stage is known as "larviciding". Proper species identification, knowledge of their habitat, and proper timing of application are essential for good control. The degree of pollution and amount of vegetation in the water influence the effectiveness of insecticides. Heavily polluted waters usually require more frequent treatment. Granular formulations are preferred in waters having heavy vegetation.

Many species of mosquitoes have developed resistance to both the chlorinated hydrocarbon and organophosphate types of insecticides. Petroleum oils (No. 2 fuel oil) are again being commonly used in Missouri for larviciding for the following reasons:

1. Aquatic stages do not become resistant to oils
2. Environmental hazard to other aquatic life is reduced
3. Conventional organophosphate and carbamate insecticides can be used for adult control, thereby delaying resistance.

Other insecticides recommended as mosquito larvicides include:

Abate at rate of 0.016 to 0.048 pound per surface acre.
Fenthion (Baytex) at rate of 0.05 to 0.2 pound per surface acre
Malathion at rate of 0.5 pound per surface acre
Petroleum oil (No. 2 fuel oil) at rate of 2 to 10 or more gallons per surface acre.

Even these low rates of Abate, fenthion and malathion may be toxic to other aquatic insect life, shrimp, crabs, fish, birds and honey bees.

Midges

Sewage lagoons, especially those that are allowed to become overloaded, frequently become heavily populated with several species of midges. A nuisance situation is created for surrounding residences when adult midges emerge from their aquatic habitat. The adult midges resemble mosquitoes in size and shape, but they do not bite or suck blood. Neither are they known to be vectors of diseases.

There are four stages in the life cycle of midges - egg, larva, pupa, and adult. The first three stages occur in water. The blood-red larvae are found on or very near the surface of sludge on the bottom of the lagoon. They are actually beneficial in that the larvae feed on and help breakdown the organic matter. Although some larvae can be found throughout the lagoon bottom, they have a preference for shallow water ranging from shore-line out to a depth of about four feet. Also, midges prefer the secondary lagoon and are seldom found in the primary lagoon receiving the raw sewage.

Proper lagoon management normally keeps the midge population within desirable levels. Consistently overloaded lagoons may develop an over abundance of midges anytime during late spring, summer and early fall. Bottom sampling of overloaded lagoons often reveals the bottom literally covered with larvae. Within some two to three weeks, a heavy adult emergence can be expected.

The objective in control of these nuisance midges is to temporarily reduce the larval populations through limited area application of granular insecticides. The granules must readily sink to the bottom, and the insecticide must be of short residual and biodegradable. Very few insecticides are registered for this use. A 1% Abate on sand granule or a 2% Abate on Celatom granule may be used at the rate of 0.2 to 0.5 pound per acre. The lower rate of application is usually all that is necessary to temporarily reduce the midge problem. Broadcast the granular formulation from the shore-line out into the lagoon for a distance of 8-10 feet or to a water depth of four feet.

Unless an effort is made to correct the overloading situation, the midge problem will redevelop within one to three months. Abate is toxic to other aquatic insects occurring in most secondary lagoons.

Filter Flies

Sewage disposal plants using trickling filters occasionally develop very heavy infestations of these small, moth-like flies. Adult filter flies are not known to be vectors of any disease, nor do they bite or suck blood. However, the nuisance effect of an overabundance of these adult flies to disposal plant laborers and to surrounding residences can be serious.

There are four stages in the life cycle of filter flies - egg, larva, pupa and adult. The first three stages occur in or at the water level. An excessive number of larvae and pupae in the filters can cause what is known as "ponding of the filter". This is a condition whereby the filter rock becomes clogged, either throughout the entire depth or near the surface, which causes pools of sewage to stand either in or on the filter. There are several other causes of "ponding".

If the "ponding" condition is caused by sloughing of filter fly larvae and pupae, or the nuisance problem becomes obnoxious, they can be controlled by periodic flooding of the filter beds and manual removal. This problem can also be controlled through the periodic addition of an insecticide either to the sewage flowing to trickling filters or to flooded trickling filters. The only insecticide known to have registration for this usage is mevinphos (Phosdrin).

Sewage Flowing to Trickling Filters

The amount of insecticide required is determined by the amount of sewage flow to the trickling filters. Sewage flow is usually expressed in terms of gallons per minute over the filters. Insecticide usage is recommended at the rate of 0.35 pound actual mevinphos per hundred gallons of sewage flow per minute. Dosage may be figured by using the following formula:

$$\left(\frac{\text{gals./min. over filter}}{100} \times 0.35 = \text{lbs. actual mevinphos}\right)$$

The insecticide may be introduced under either direct or cycle flow.

Flooded Trickling Filters

The insecticide added to filters flooded to the top of the rock surface provides a longer period of contact with the pest. Consequently, lower concentrations are effective. This type of treatment is particularly desirable where large amounts of sewage flow to the filter and a recirculation process exists. Determine in gallons the volume of sewage present in the flooded filter. Insecticide usage is recommended at the rate of 0.05 pound actual mevinphos per 100 gallons of sewage. The insecticide can be added at a number of points around the side of the filter and distributed by allowing the arms of the filters to make several revolutions. Following application and distribution, the treated sewage in the filter should be held for a minimum of five hours. This holding period enhances control and also allows the biodegrading process of the insecticide to begin. Dosage may be figured by using the following formula after the volume of sewage in the filter has been determined:

$$\left(\frac{\text{gals. of sewage in filter} \times 0.05}{100} = \text{lb. actual mevinphos}\right)$$

Biological Properties of Mevinphos (Phosdrin)

This is an organophosphate insecticide which is very highly toxic to warm-blooded animals by all exposure routes (oral, dermal and inhalation). All safety precautions must be followed when handling and/or using this insecticide. This insecticide has a wide spectrum of insect control, but uses are limited by its short residual activity. However, this short residual activity is an advantage in this use on trickling filter beds without undue hazard of effluent and stream pollution. The rapid loss of residues by volatilization, hydrolyzing, and water dilution precludes any appreciable residual toxicity beyond a few hours after application. Its LC_5 (concentration to kill 5%) to fish is less than 10 ppm.

Section 8. References

1. EPA compendium of Registered Pesticides, Volume I Herbicides and Plant Regulators. 1975.
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2. Guidelines for Weed Control. August 1973.
   Agriculture Handbook No. 447, Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C. (For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

3. Herbicide Handbook of the Weed Science Society of America. Third Edition. 1974. (For sale from Weed Science Society of America, 425 Illinois Building, 113 North Neil Street, Champaign, Illinois 61820. Price $5.00.)

4. Herbicide Manual for Noncropland Weeds. August 1970.
   K.S. Quisenberry, et. al., Agriculture Research Service, U.S. Department of Agriculture.
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5. Principles of Plant and Animal Pest Control, Volume 2. Weed Control. 1968. Publication 1597. National Academy of Sciences, Washington, D.C.

6. Water Quality Criteria, Second Edition. 1963.
   Edited by J. E. McKee and H. W. Wolf., Publication No. 3-A, The Resources Agency of California, State Water Quality Control Board, Sacramento, California 95814.

Additional information on proper use of registered pesticides for most effective aquatic pest control and least or no effect on non-target organisms can be obtained from: (1) Publications referred to in this manual, (2) Information available through County Extension offices from State land grant universities, (3) State conservation departments, and (4) Information from product labels and manufacturers of pesticides approved by EPA for use in aquatic areas.